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Research paper

Spatial variations in typhoon activities and precipitation trends over the Korean Peninsula

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Abstract

Global warming has caused changes in air temperatures, ocean heat content, and sea levels, and these changes might strengthen tropical cyclones (TCs) around the Korean Peninsula and exacerbate the damage that these storms can have on both coastal and inland communities. Therefore, there is an urgent need in this region to update hazard mitigation plans for TCs and improve community resilience measures to cope with the corresponding damage. In accordance with such efforts, this study aims to build quantitative statistical datasets about typhoons in the northwestern Pacific Ocean that approach the Korean Peninsula and use these data to analyze the characteristics of typhoon activity (e.g., TC genesis location, TC path, recurving position, and intensity) and the accompanying spatio-temporal changes in rainfall. During 1966 to 2009, significant changes in the timing, paths, and frequencies of strong summer typhoons were observed along with increases in the intensity of summer typhoon rainfall over portions of the Han River basin and the Nakdong River basin. We hope that these findings will provide foundational information for disaster prevention efforts and assist natural resource managers to protect river basins and secure water resources.

Keywords: KP-approach typhoons; Tropical cyclone (TC) activity; TC landfall; Korean Peninsula

1. Introduction

In early November 2013, Typhoon Haiyan, one of the most powerful tropical cyclones (TC) in history, hit the Philippines. The typhoon was accompanied by strong winds of up to 314 km per hour and a tsunami that was about 6–7 feet (1.8–2.1 meters) in height. Typhoon Haiyan resulted in great losses to life and property and up to 6100 deaths and 27,000 injuries were reported; property losses were estimated to have reached 12.9 billion USD (Dash et al., 2014). Along with the acceleration of climate change, typhoons generated in the North Pacific are expected to grow even stronger, and northern locations such as the Korean Peninsula (KP) may be exposed to potential dangers from super typhoons like Haiyan (Kim and Jain, 2011; Kim et al., 2012; Li et al., 2012; Son et al., 2014).

On account of changes in the climate, much research has been conducted to analyze changes in the activities of typhoons such as their frequency and strength, and to investigate changes in large-scale air or sea patterns that may be driving such change (Kamahori et al., 2006; Knutson et al., 2010; Choi et al., 2013a). Kamahori et al. (2006) reported that the frequency of powerful typhoons has increased continuously for the last 30 years and they emphasized that communities need to devote more attention to developing plans and measures for typhoon damage prevention. Knutson et al. (2010) estimated the intensity of the typhoons coming from different locations of generation with seven climatic models and all of the climatic models showed that the intensity of typhoons generated in the western Pacific Ocean will increase.

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Choi et al. (2013b) conducted a statistical analysis of the typhoons that have landed on the KP for a period of 60 years (1951–2010) and the results showed that since 1981, the frequency of landing has increased dramatically; the data also suggested that changes in air pressure, wind, and sea conditions were responsible for the changes in typhoon activities.

It is very important to build objective as well as accurate datasets about typhoons because such data can be widely used as foundational information to develop disaster prevention plans and design infrastructure at a national level that is more resistant to typhoon related damage. Such datasets can also be used to forecast the long-term changes in typhoons that can be expected with climate change (Moon and Choi, 2011).

Recently, Park et al. (2006) analyzed the occurrences of typhoons and their statistical characteristics (frequency, strength, rainfall, and degree of damage according to the path of a typhoon) with data on typhoons that have been accumulated for about 50 years (1954–2003) to identify typhoons that have influenced the KP. Kwon and Rhyu (2008) suggested that researchers use more specialized criteria for determining whether a typhoon has influenced the KP. These criteria include four factors: the location of the center of a typhoon, the boundary line of the offering by the Korean Meteorological Agency (KMA), the category of a typhoon, and the 34-knot wind path. The KMA presents statistical data about typhoons when they pass through the domain of the KP (32°N–40°N, 120°E–138°E) and influence the KP. However, different researchers or observers sometimes apply different subjective criteria to determine a typhoon that has influenced the KP and occasionally this results in similar-sized typhoons being classified differently (i.e., into one that has influenced the KP or into one that has not influenced the KP). This lack of consistency is still present up to now, and it has been hard to establish objective data about typhoons (Park et al., 2006; Kwon and Rhyu, 2008; Moon and Choi, 2011).

Because global warming has caused changes in air temperatures, ocean heat content, and sea levels, and these changes might strengthen TCs around the KP and exacerbate the damage that these storms can have, there is an urgent need in this region for typhoon-related research. Data from such studies are essential for updating hazard mitigation plans for TCs and improving community resilience measures to cope with the corresponding damage (Kim et al., 2012; Son et al., 2014). In this study, we aim (1) to build objective and quantitative statistical datasets about KP-affected typhoons in the northwestern Pacific Ocean, (2) to use these data to analyze the characteristics of typhoon activity (e.g., TC genesis location, TC path, recurving position, and intensity) and the accompanying spatio-temporal changes in rainfall. Specifically, we analyzed typhoon activity near the KP during 1966–2009.

2. Data and methodology

This study utilized monthly rainfall data from the Global Precipitation Climatology Centre (GPCC) and also daily rainfall data provided by the Water Resources Management System (WAMIS) in Korea. Daily rainfall data for basins in the KP are the weighted average by the Thiessen polygon approach for a network of over 140 meteorological observatories, and these data include information for 113 middle-scale basins including five major river basins and coastal basins in the KP. These averaged hydrologic data for the basins can be effectively utilized in Korea for areas that lack observatory data to analyze the characteristics of hydrologic change in each unit basin and establish med- and long-term water resources plans (Kim and Jain, 2011).

Data on typhoons that occurred in the Pacific Northwest over a 44-year period from 1966 to 2009 were obtained from the Regional Specialized Meteorological Centre (RSMC) Tokyo-Typhoon Center (Japan Meteorological Agency, 2014: http://www.jma.go.jp/en/typh/). These data provide information about the intensity and the location of the center of a typhoon for every six hours. This study did not apply the ambiguous criteria for "typhoons influencing the KP" (KMA, 1996), which may differ according to one's subjective judgment; instead, we employed the criteria for "typhoons adjacent to the KP" (Moon and Choi, 2011) in order to build objective and consistent statistical datasets for the typhoons that could be used to analyze the seasonal activity. Here, the criteria for "typhoons adjacent to the KP" were limited to cases where the eye of a typhoon passed through a particular domain (28°N–40°N, 120°E–138°E) one or more times. Fig. 1 shows the paths of 327 typhoons that passed through the typhoon domain adjacent to the KP during 1966–2009.

To compare the seasonal activity characteristics of those typhoons, they were classified according to their periods of occurrence, i.e., summer (June–August) or fall (September–October), and several types of data were collected and analyzed. These data included the location of development (TC genesis location), time for development, recurving position, TC path, and change of atmospheric pressure in the center. In addition, the amount of rainfall that occurred at the point where the typhoon passed through the domain adjacent to the KP was noted, and this rainfall is referred to as typhoon accompanying rainfall herein. In order to analyze the activities of the typhoons and the tendencies in typhoon rainfall, this study conducted Mann–Kendall trend analyses (Mann, 1945; Kendall, 1975; Helsel and Hirsch, 1992), which represent a type of non-parametric statistical test. We also performed Poisson regression analyses (Faraway, 2006) to analyze countable data. To determine the statistical significance of the analysis results and reach conclusions, we applied two-sided significant tests at the 5% and 10% significance levels.

3. Changes in characteristics of tropical cyclone (TC) activity

As global warming has caused a rise in air temperatures and ocean heat content, which could increase energy sources of the TCs that influence the KP and cause extensive damage, this study attempted to analyze the changing trends in TC activity and accompanying rainfall over the KP. The results for the rainfall analyses are presented later in Section 4. This section presents the results for changes in TC activity.

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